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BARK TEMPERATURES IN PONDEROSA PINE DURING ATTACK BY DENDROCTONUS BREVICOMIS LEC.

by

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BARK TEMPERATURES IN PONDEROSA PINE DURING ATTACK BY DENDROCTONUS BREVICOMIS LEC.

Some attention has been previously given to air and subcortical temperatures (Rust (1), Beal (3)). These investigations, however, were made during periods of extreme cold weather to determine the effect on overwintering bark beetle brood.

The present study was undertaken (1) to determine the relation between air temperature and that of the infested bark at different points on the bole, and (2) to determine in what way these air and bark temperatures relate to development.

Methods

These tests were performed at Hackamore in the Modoc National Forest, and covered the period from June 15 to July 26, 1935. The full period of attack was not followed because of lack of funds.

The two trees selected for the experiment were so situated that there was little shading of the trunk by other trees during the hours of sunlight. The first, designated as BE 87, was a typical mature slow growing tree; the limbs were large and the lowest ones came to within 35 feet of the ground; a previous insect attack had killed about 10 feet of the top. Additional data as follows:

Class	4C (Keen)
Height	6 logs
D.B.H.	40 inches
Bark thin	

The limbs were removed up to a height of 50 feet to eliminate the factor of shade as much as possible. A ladder was built up the northwest side of the tree as shown in Photo nos. 3 and 4. Thermocouples were installed in the following positions:

5 feet
north
southwest

10 feet
air temperature - north side
north
northwest
west
southwest
south
southeast
east
northeast

15 feet
north
southwest

20 feet
air temperature - north side
north
northwest
west
southwest
south
southeast
east
northeast

25 feet
north
southwest

30 feet
air temperature - north side
north
southwest

35 feet
north
southwest

40 feet
air temperature - north side
north
southwest

A screen cage was placed on the south side of the tree as shown in Photo no. 5, and a forced attack started June 22, 1935. The attack was very successful, the attracted beetles filling in well up to the limbs.

The second tree, BE 88, had formerly been one of a dense stand, the other members of which had been killed previously by bark beetles. As a result of the former crowded condition, the limbs of this tree, except for the top 25 feet, were all on the east side. Additional data as follows:

Class	3C (Keen)
Height	4 logs
D.B.H.	24 inches
Bark moderately thick	

The tree was limbed up to a height of about 67 feet and a ladder of pole spikes made up the northwest side. Incidentally, this ladder was much more satisfactory than the one of lumber built on No. 87, in that it was more quickly installed and threw considerably less shade on the bark. The thermocouples were placed as follows:

10 feet
north
southwest

20 feet
air temperature - north side
north
northwest
west
southwest
south
southeast
east
northeast

30 feet
north
southwest

40 feet
air temperature - north side
north
southwest

50 feet
north
southwest

60 feet
air temperature - north side
north
southwest

A cage was placed on the south side as was done for tree No. 87, and the forced attack started July 16, 1935. Progress was a little slow, but free flying beetles eventually filled in well.

The thermocouples used were encased in a short piece of brass tubing which was attached to a black fiber handle (photo no. 10). These were made and calibrated in Berkeley. When installed, the brass tubing was inserted in the bark with the sensitive tip at the desired depth and the emergent portion of the brass tubing was protected by a fiber collar (photo nos. 9 and 10). Except as otherwise noted, all couples were in the bark $\frac{1}{8}$ inch. Insofar as was possible, each thermocouple was installed in the center of a bark plate rather than near the edge. However, a subsequent test showed the bark temperature in the center of the plate to be the same as that within one inch of the fissure.

Air temperature at the different heights was measured by means of thermocouples in special boxes which were suspended on the north side of the tree (photo nos. 5 and 7). These boxes were 8 inches on a side and made of louvered strips of box fiber over a wood frame; the outside was painted white to reduce the effect of heat absorption.

Most of the thermocouples were made of 28 gauge enameled single silk covered copper and constantan wires and the leads were of the same wire. Only one constantan lead was used, it being common to all couples. A separate copper lead was required for each. These leads terminated at a switchboard, for making connections with the potentiometer. The circuits were laid out on the ground at the base of the tree, the joints soldered, the wires bound together, and then the resulting cable was hoisted into position as a unit. It should be mentioned that all soldering was done with resin, rather than acid flux to avoid the possibility of corroding the wire. It was also necessary to use extreme care to avoid kinking the wires, as such a condition would possibly cause an erroneous reading.

On both trees, a Foxboro bulb type recording thermograph was installed with the bulb placed in the bark at a height of 10 feet and at a southwest exposure. The thermocouple at that position was placed as close to the bulb of the thermograph as possible. The chief difficulty in making this set up was that the exact position of the sensitive portion of the thermograph bulb could not be exactly determined without cutting into the bark, so conditions between the bulb and the adjacent thermocouple may not have been entirely comparable. On tree No. 87, the emergent portion of the thermograph bulb, the so-called non-sensitive portion, was protected from radiation by a covering of asbestos paper; because of an inadequate supply of this material, the thermograph bulb on tree No. 88 was not so protected.

The plan had been to take readings every hour during the day, but due to the occasional development of short circuits in a portion of the wiring that was not enamel insulated and to the necessity of changing positions of some of the thermocouples, the interval between readings was frequently somewhat longer. One series of readings was continued over a period of 32 hours.

Results

The readings for each day were plotted for purposes of comparison and the most typical of these graphs are included here to show the trends.

With the set up as first made on tree No. 87, it was found that the indicated temperatures were very high in the portions of the bark exposed to the sun, indicating that the thermocouples were being influenced by radiation. To reduce this factor, the handles of all thermocouples except two, which were under the cage, were painted white.

The most satisfactory phase of the work was the measurement of air temperatures. Excellent correlations were obtained with the recording thermograph in a standard Weather Bureau housing, located in a cleared area near the laboratory and about 200 yards from the trees. These results are best expressed in the graphs (graphs 1 to 4). It will be seen that for both trees there is a slight tendency for the air near the ground to be warmer during the day and cooler at night than at the upper levels; this difference is probably due to radiation during the day and stratification of air at night. The differences are so slight, however, that they would seem to have little significance.

The measurement of bark temperatures, however, was not entirely satisfactory because of absorption and conduction of heat by the thermocouples. Even after the thermocouple handles were painted white, as described above, the readings ran high, frequently well above 100°, during the time the points measured were exposed to the sun. That such temperatures are erroneous is indicated by the fact that the thermograph record of bark temperatures was consistantly lower during the

hottest part of the day - a matter to be discussed further. The investigations of Miller (2) and Beal (3) although made under somewhat different conditions from those of the present study, also indicate that such temperatures would be unfavorable to development of D. brevicomis larvae, whereas the brood on these two trees developed in a normal manner. An effort was made to develop a thermocouple which would be more reliable. One consisting of wires alone, without the protective brass stem, or the handle, was inserted to the desired depth in a hole in the bark made just large enough to receive the junction. After the thermocouple was in place, the hole was closed by a wooden plug. This type gave the most extreme readings of any tried. The next modification was a thermocouple with the brass stem, but without the fiber handle, and this was also unsatisfactory. Various attempts at shielding were made without any great change in results, except where a sizeable area of bark was shaded. So although the first mentioned type was not entirely accurate, it is as good or better than any of the others tested.

To serve as a check of one method against the other, the readings of the thermograph, the adjacent thermocouple, and a mercury thermometer inserted at the same point, were all plotted together (graphs 5 to 10). There was a decided tendency for the thermocouple reading to be higher until the tip was inserted to a depth of three-fourths of an inch, instead of half an inch; on the other hand, after the change of depth was made, although the readings during the daylight hours check fairly well, there was considerable difference in the night readings. The thermograph readings are probably correct in that the instrument had been checked both for lag and effect of radiation on the emergent portion of the bulb, and the thermometer readings checked within one or two degrees.

The ring of thermocouples at 10 and 20 foot levels on tree No. 87 and the one at 20 feet on No. 88 were installed to compare the temperatures at different points on the circumference of the tree. The ring installation on No. 88, however, was changed and the couples used for the tests on the different types of thermocouples. The different readings at 10 feet are not entirely comparable because two of the thermocouples south and southwest were covered by the cage, and the former was so located that the handle could not be painted white when the others were, and consequently gives rather high readings. If we disregard the south thermocouple, then it is evident from the graphs (graphs 21 and 22), that the southwest and west portions of the bole are the warmest, with the west side attaining the highest temperature and the southwest portion attaining the highest sustained temperature. The difference in temperature over a 24 hour period could be expressed on a quantitative basis, but since, as pointed out above, the experimental error is large, such an expression would be valueless. Turning now to the 20 foot ring, we find in the graphed results (graphs 23 to 25) trends similar to those in the 10 foot ring. In this case the west side shows peaks somewhat higher than the others. This is probably due to the thermocouple, of necessity, being placed very close to the side of the ladder which thus served as a reflecting surface. The

other readings indicate that the south side is warmest in the course of a day, although higher peaks may be reached for short periods at other points.

In comparing the 10 foot and 20 foot rings, it seems that there is a slight tendency for the former to be somewhat warmer and further evidence on this point is to be gained by comparing readings from the same points on the circumference of the trunk, but at different heights. In the readings taken from the southwest exposure on tree No. 87 (graphs 11 and 12), we find a distinct tendency toward lower temperatures at the higher levels. The same is true of tree No. 88 (graphs 13 to 15), although the difference is not so apparent late in the day because of shading on the lower portions of the bole. In comparing different levels on the north side of the tree where direct sunlight is less of a factor, the same tendency toward lower temperatures at the higher levels is evident. On tree No. 87 (graphs 16 and 17), the difference is not very pronounced and the greatest change occurs between 5 and 10 feet. In tree No. 88, (graphs 18 to 20) however, there is a very decided difference, probably because sunlight is more of a factor on a small diameter tree. In the absence of sunlight, all the bark temperatures tend to approach the air temperature, and the lower levels may become cooler than the higher ones, the difference, however, is rather slight.

Since it was not possible to continue this work over the necessary period of time, data on the relation of bark temperatures and brood development are not included. This phase, based on temperatures recorded by bark thermographs, will be presented by Dr. Salman at a later date.

Discussion

From this preliminary work no broad or final conclusions can be made as to differences of bark temperatures at different points of the tree, however, some very definite points are apparent. From the thermograph records of bark temperatures of the trees studied, it seems that the temperatures derived from thermocouple readings are somewhat in error; and the source of error seems to be radiation and conduction through the thermocouples. Since, however, radiation would have some warming effect on the bark, even though not to the extent indicated by the thermocouple readings, we should be justified in pointing out the existing trends, and certain trends are quite evident. First, there appears to be little difference in air temperatures at different heights except for a very slight effect of radiation. This however, will vary with different sites. Second, the bark at the base of the trees is warmer than that higher on the bole during the day and slightly cooler at night. This is probably due to radiation from the ground to the bark during the day and in the opposite direction at night and will also vary with different locations. Third, the bark temperature tends to rise above the air temperature on exposure of the trunk to the sun, and when shaded the temperature of the bark tends to revert to the same level as the air temperature. There is considerable lag in these changes, however, so that the bark temperatures do not reach the lower extremes of the air temperatures. Fourth, the warmest side of the

trunk lies in the quarter of the circumference between the west and south exposures. Fifth, the bark temperatures recorded by the bulb type thermograph at a given point are quite representative of the bark temperatures at other points on the same side of the tree, unless shaded for different periods.

Recommendations for further investigations

In case it should be deemed feasible at some future time to continue the study of bark temperatures, the writer is including a few suggestions which may facilitate the work. The methods worked out in this preliminary study have proven quite satisfactory, except for the type of thermocouple. Before any further work is undertaken, laboratory tests should be made in order that a more satisfactory type may be developed. One suggestion that comes to mind is that the wires be run into the bark on an angle so that two or three inches of the wire lie under the bark and then to protect several inches of the exposed portion of the wire by covering with pieces of bark. Another possibility is the use of asbestos paper shields.

After a suitable type of thermocouple has been evolved, it would be desirable to repeat the study using a similar set up but beginning the readings before the attack starts and continuing until well after the beetles leave the tree. A similar study on trees infested with the mountain pine beetle might also be of value.

Summary

1. This study was undertaken for the purpose of determining the relation of air temperatures and bark temperatures at the base of the tree to bark temperatures at other points on the bole, during an attack by Dendroctonus brevicomis Lec., and the bearing these temperatures had on brood development.

2. Bark and air temperatures were measured by means of thermocouples and potentiometer. These determinations were checked by a bark thermograph and mercury thermometer at the base of the tree.

3. The type of thermocouple used proved to be inaccurate under extreme temperatures, and data could not be expressed on a quantitative basis.

4. The following points were established:

(a) Air temperature is the same at different heights along the trunk, except for a slight effect of radiation at the base.
(b) Probably due to radiation, the bark temperatures at the base of the tree reach slightly higher and lower extremes than those higher on the bole.

(c) Bark temperatures in areas exposed to the sun tend to rise above air temperature, and when shaded tend to revert to air temperature. There is considerable lag in these changes, so that bark temperatures do not reach the lower extremes that air temperatures do.
(d) The warmest side of the trunk lies between the west and south exposures.
(e) Where shade is not a modifying factor, bark temperatures recorded by a bulb type thermograph at a given point are representative of the bark temperatures at other points on the same side of the tree.

5. Since it was necessary to close this investigation before its completion, data on bark temperatures and brood development are not included.

Acknowledgments

The writer wishes to thank Mr. J. M. Miller, Senior Entomologist, and Dr. K. A. Salman, Associate Entomologist, under whose supervision this study was conducted, for valuable suggestions and advice; and Mr. J. E. Patterson, Assistant Entomologist, for aid in preparing the photographic material.

References

1. 1926 Rust, H. S. Experiment to Determine Relationship of Bark and Air Temperatures. (425 Db 10)

2. 1931 Miller, J. M. High and Low Lethal Temperatures for the Western Pine Beetle. Jour. Ag. Res. V 43: 303-321.

3. 1934 Beal, J. A. Relation of Air and Bark Temperatures of Infested Ponderosa Pines During Subzero Weather. Jour. Ec. Ent. V 27: 1133-1139.

Photo No. 1

Tree No. 87. Few lower limbs removed. Photo by J. M. Miller.

Photo No. 2

Tree No. 87. Removing limbs. Photo by J. M. Miller

Photo No. 3

Tree No. 87. Removing limbs. Photo by J. M. Miller.

Photo No. 4

Tree No. 87. West side. Showing ladder and louvered boxes for taking air temperature.

Photo No. 5

Tree No. 87. East side. Showing cage, thermograph, housing, louvered boxes for air temperature, and instrument table.
Photo by K. A. Salman

Photo No.6

Tree No. 88. Before removal of limbs.

Photo No. 7

Tree No. 88. Rigging tree, After removal of limbs.

Photo No.8

Tree No. 88. Cage, thermograph, and potentiometer.

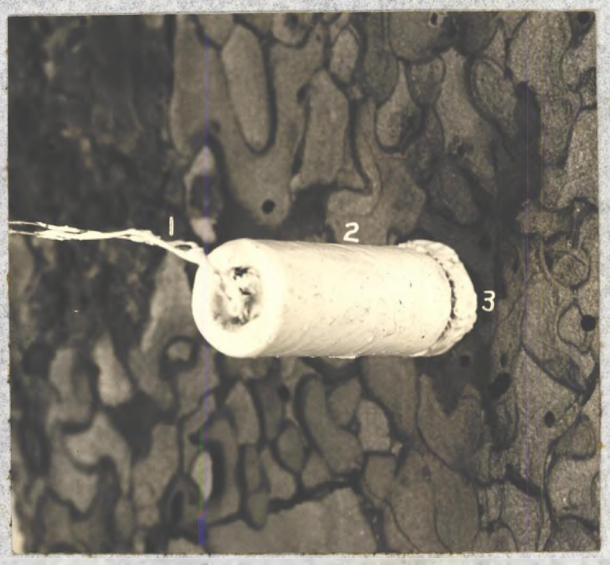


Photo No. 9

Thermocouple in position in bark.

1. Thermocouple wires
2. Fibre handle
3. Fibre collar

Photo No. 10

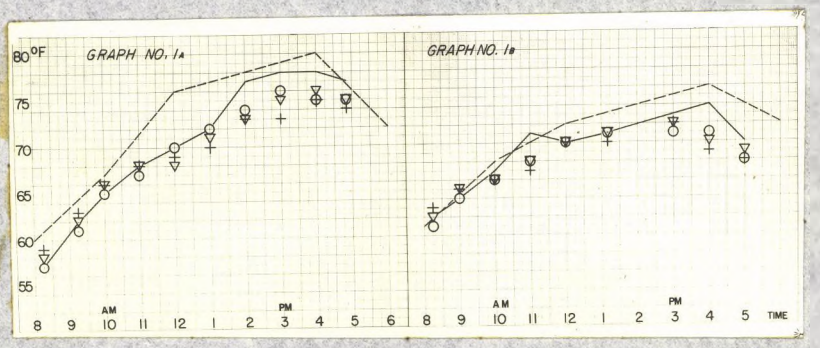
Thermocouple and protective collar.

1. Sensitive tip
2. Brass stem
3. Fibre handle - painted white
4. Thermocouple wires
5. Fibre collars - painted white

Photo by J. E. Patterson

Air temperatures at different heights along the trunk

Tree No. 87



----- Air temperature as recorded at the laboratory.

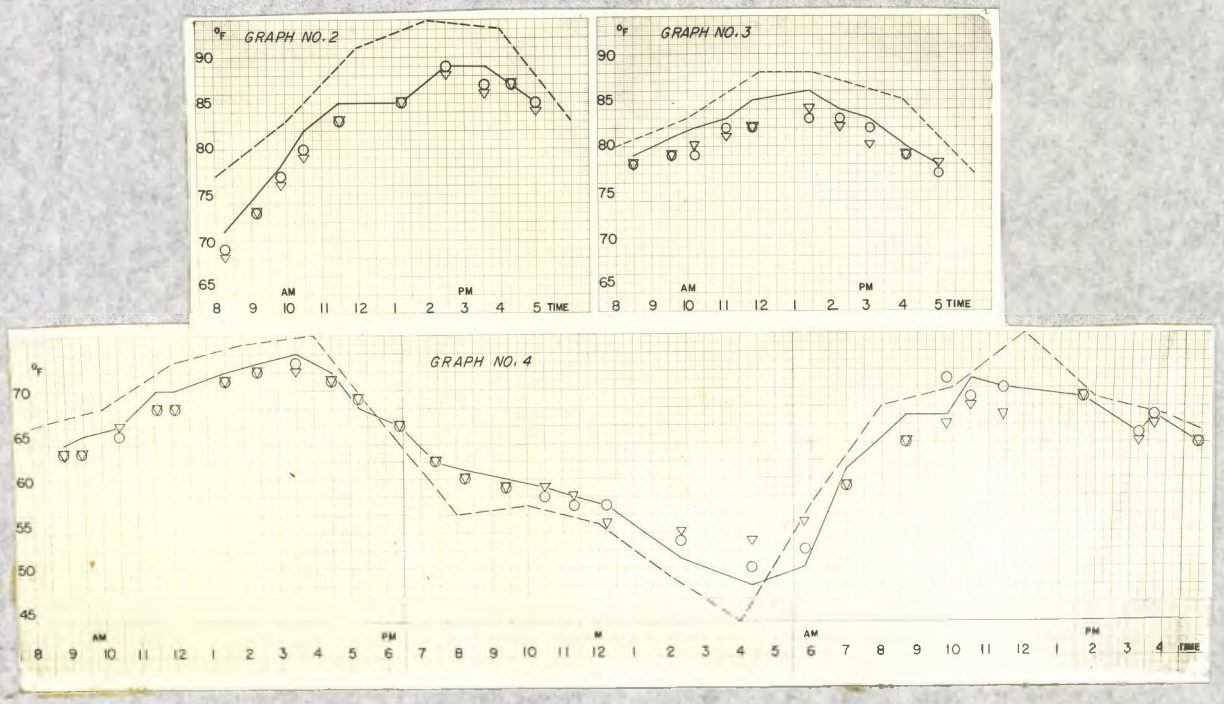
——— Air temperature near the bole 10 feet above the ground.

○ " " " " " 20 " " " "

△ " " " " " 30 " " " "

\+ " " " " " 40 " " " "

Tree No. 88



-·-·-·- Air temperature as recorded at the laboratory.

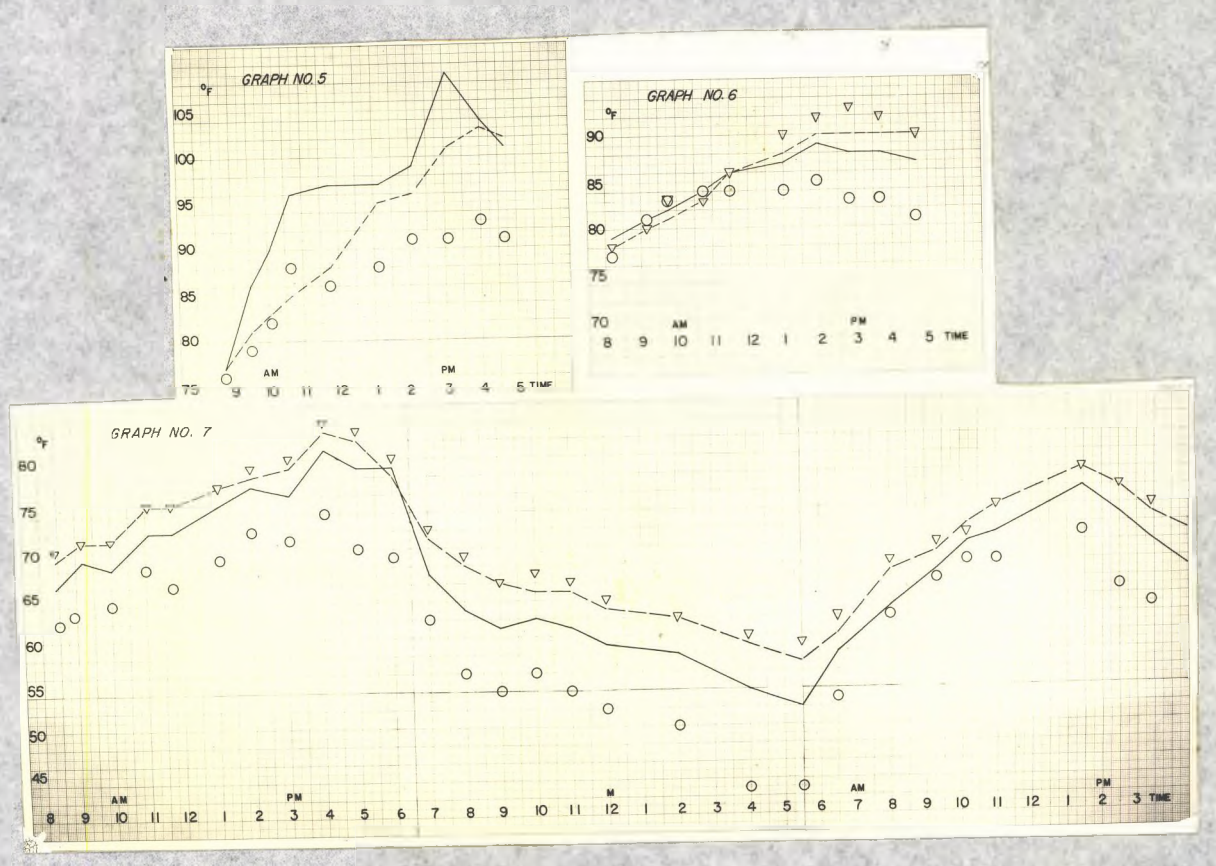
——— Air temperature near the bole 20 feet above the ground.

○ " " " " " 40 " " " "

△ " " " " " 60 " " " "

A comparison of bark temperatures taken by different methods

Tree No. 87



_ _ _ _ Bark temperature recorded by bulb type thermograph

_____ " " indicated by adjacent thermocouple

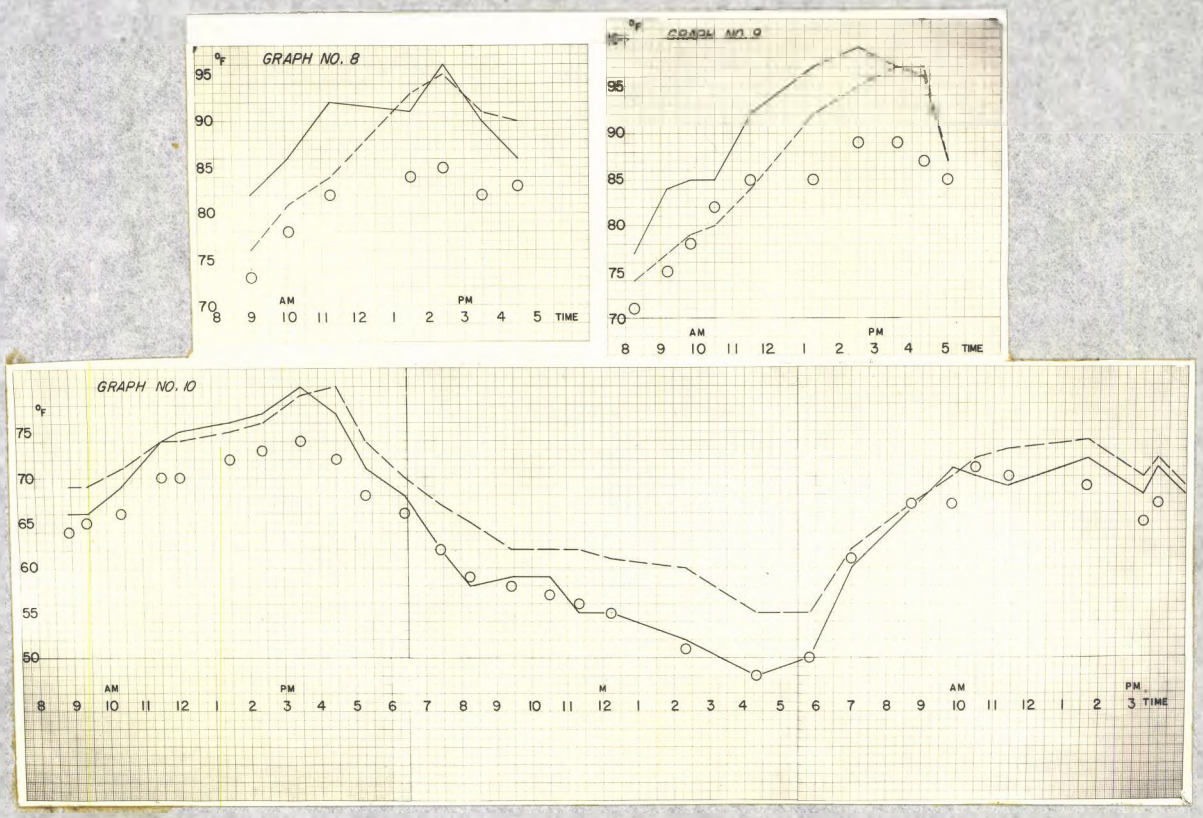
▽ " " " " " thermometer

○ Air temperature

Note: No. 5 was taken with the thermocouple set $\frac{1}{2}$" deep, and Nos. 6 and 7 with the couple $\frac{3}{4}$" deep.

A comparison of bark temperatures taken by different methods.

Tree No. 88



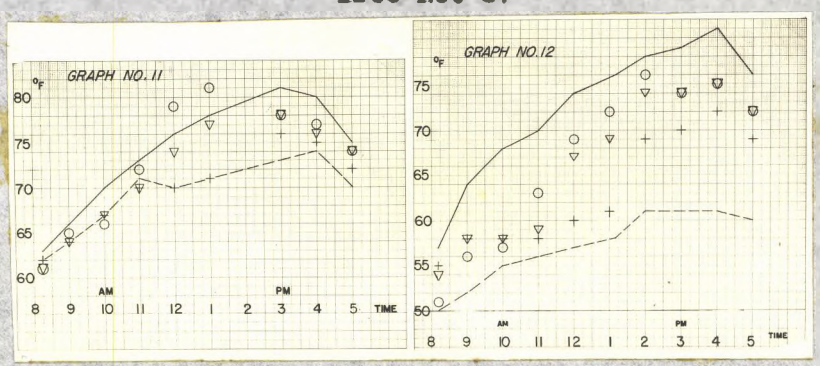
----- Bark temperature recorded by bulb type thermograph

——— " " indicated by adjacent thermocouple

○ Air temperature

Bark temperatures as indicated by thermocouples - Southwest exposure at different heights on the trunk

Tree No. 87



——— Bark temperature southwest exposure at 10 feet

○ " " " " " 20 "

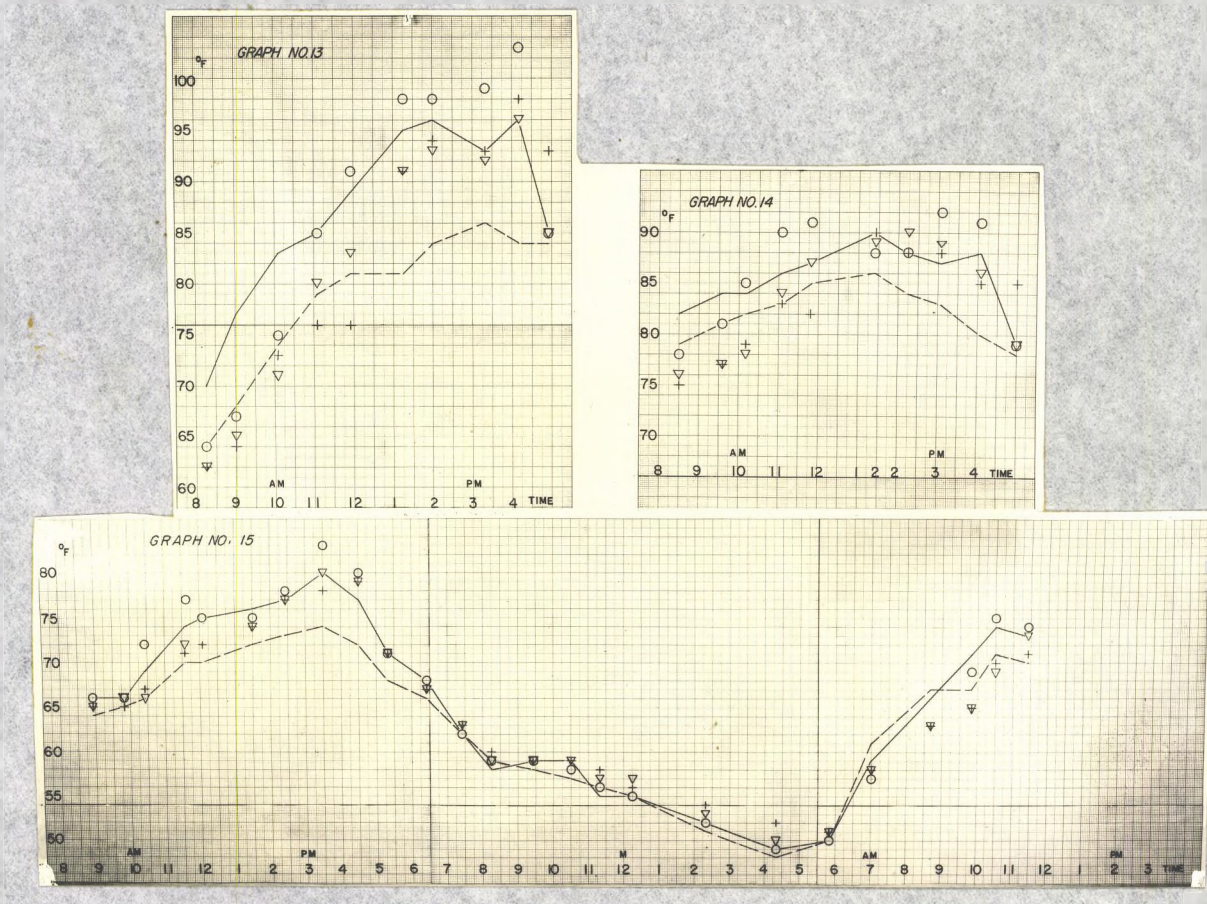
▽ " " " " " 30 "

\+ " " " " " 40 "

- - - - - Air temperature

Bark temperatures as indicated by thermocouples - Southwest exposure at different heights on the trunk.

Tree No. 88



_____ Bark temperature southwest exposure at 10 feet

○ " " " " " 20 "

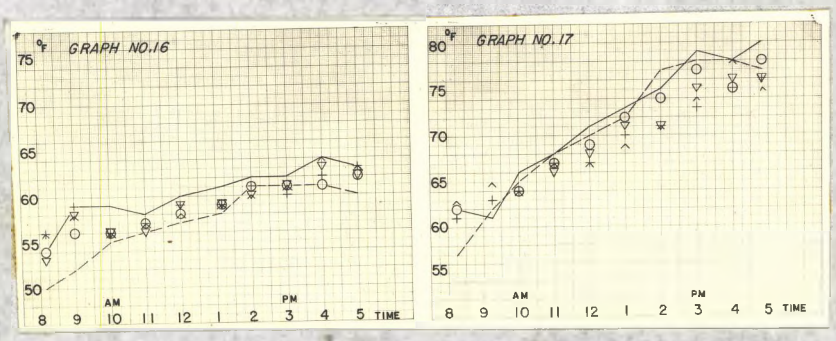
▽ " " " " " 40 "

\+ " " " " " 60 "

– – – – Air temperature

Bark temperatures as indicated by thermocouples - North exposure at different heights on the trunk.

Tree No. 87



———— Bark temperature, north exposure at 5 feet

○ " " " " " 10 "

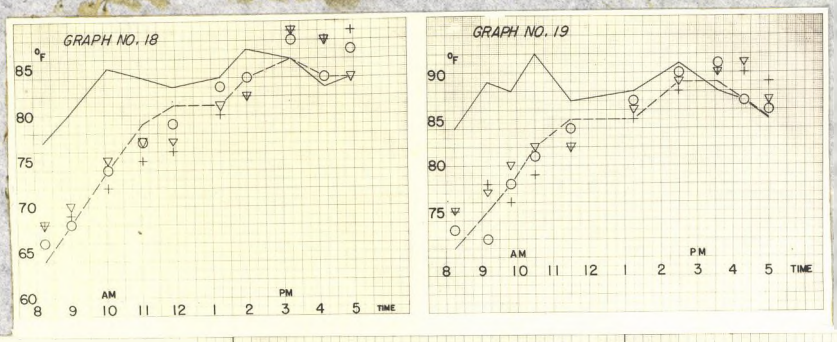
▽ " " " " " 20 "

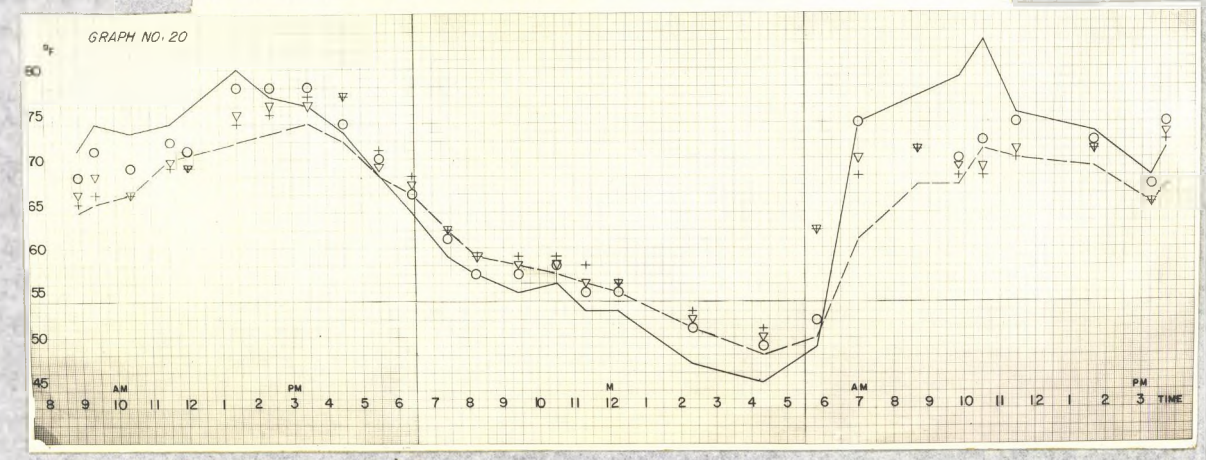
\+ " " " " " 30 "

^ " " " " " 40 "

– – – – – – Air temperature

Tree No. 88





———— Bark temperature, north exposure at 10 feet

○ " " " " " 20 "

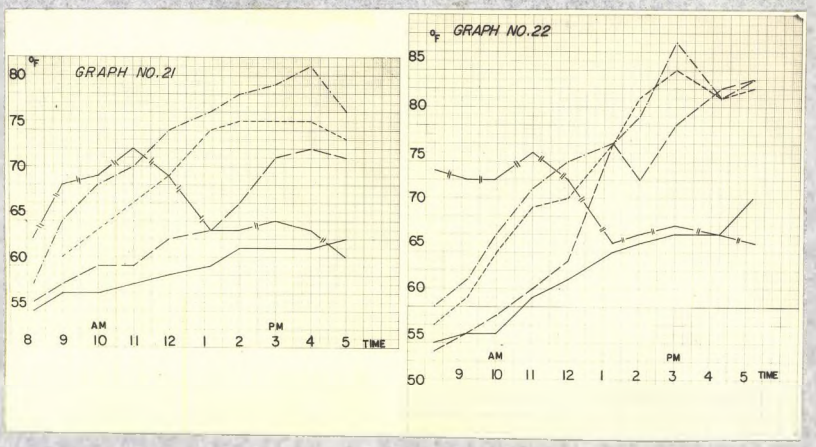
▽ " " " " " 40 "

\+ " " " " " 60 "

– – – – – Air temperature

Bark temperatures as indicated by thermocouples at a height of 10 feet and at different positions of exposure on the trunk.

Tree No. 87



———— Bark temperature at north exposure

———— — " " " west "

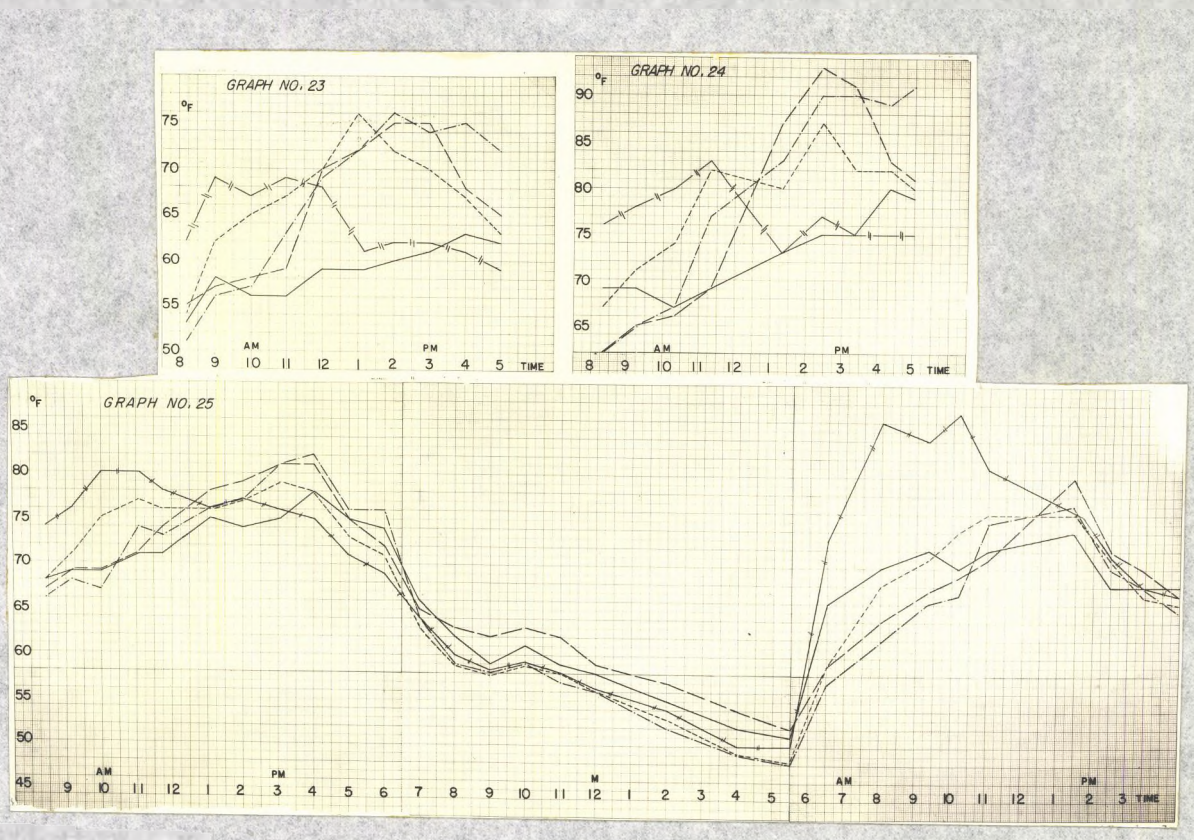
———— - ———— " " " southwest "

— — — — — — " " " south "

//——// " " " east "

Bark temperatures as indicated by thermocouples at a height of 20 feet and at different positions of exposure on the trunk.

Tree No. 87



———— Bark temperature at north exposure

— — — " " " west "

— · — " " " southwest "

– – – – " " " south "

//——// " " " east "